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Effects of heavy truck offtracking on Montana highways

MONTANA DEPARTMENT OF HIGHWAYS

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EFFECTS OF HEAVY TRUCK OFFTRACKING ON MONTANA HIGHWAYS

Prepared by:

Program Development Division
Planning and Statistics Bureau
Rural Planning Section Sept., 1990

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INTRODUCTION

Trucking is a major and versatile component of Montana's freight transportation system. Industry fundamental to Montana's economic base including agriculture, mining, construction, and timber, rely on trucking for the transport of goods and materials. In many of Montana's rural areas, trucking has become increasingly important due to the loss of railroad service. Montana recognizes the socio-economic impact of trucking and continually works toward meeting the needs of the trucking industry. However, as allowable truck lengths have increased, so have the related problems.

In response to recent questions concerning heavy truck offtracking on Montana's rural and urban Primary routes, the Montana Department of Highways (MDOH) Rural Planning Section conducted a study focused on truck turning characteristics, problems related to offtracking, and why offtracking problems exist in Montana.

The objective of this report is to present the information compiled during the study and provide an evaluation of current and future offtracking conditions in Montana.

TRUCK TURNING CHARACTERISTICS

Because of a truck's long wheelbase, its rear wheels do not follow the same path as its front wheels when making a turn. The difference in this path is defined by the terms offtracking and swept path. Offtracking is defined as the difference in the paths of the front-most and rear-most inside wheel of a vehicle as it negotiates a turn (Millar, et al.). This distance may also be measured between the tracking of the front and rear outside wheels, or the center of the front and rear axle, but its value will be the same. The magnitude of offtracking is affected in combination by vehicle length, number and location of articulation points, length of the arc and type of curve, and the speed and turnability of the wheels (Fambro, et al.).

Swept path width is defined as the amount of roadway width the vehicle takes up when negotiating a curve, or the amount of offtracking plus the width of the vehicle. From the perspective of highway design, swept path is the relevant measure of offtracking (Skinner, et al.). Figure 1 illustrates the relationship between the swept path width and offtracking of a vehicle.

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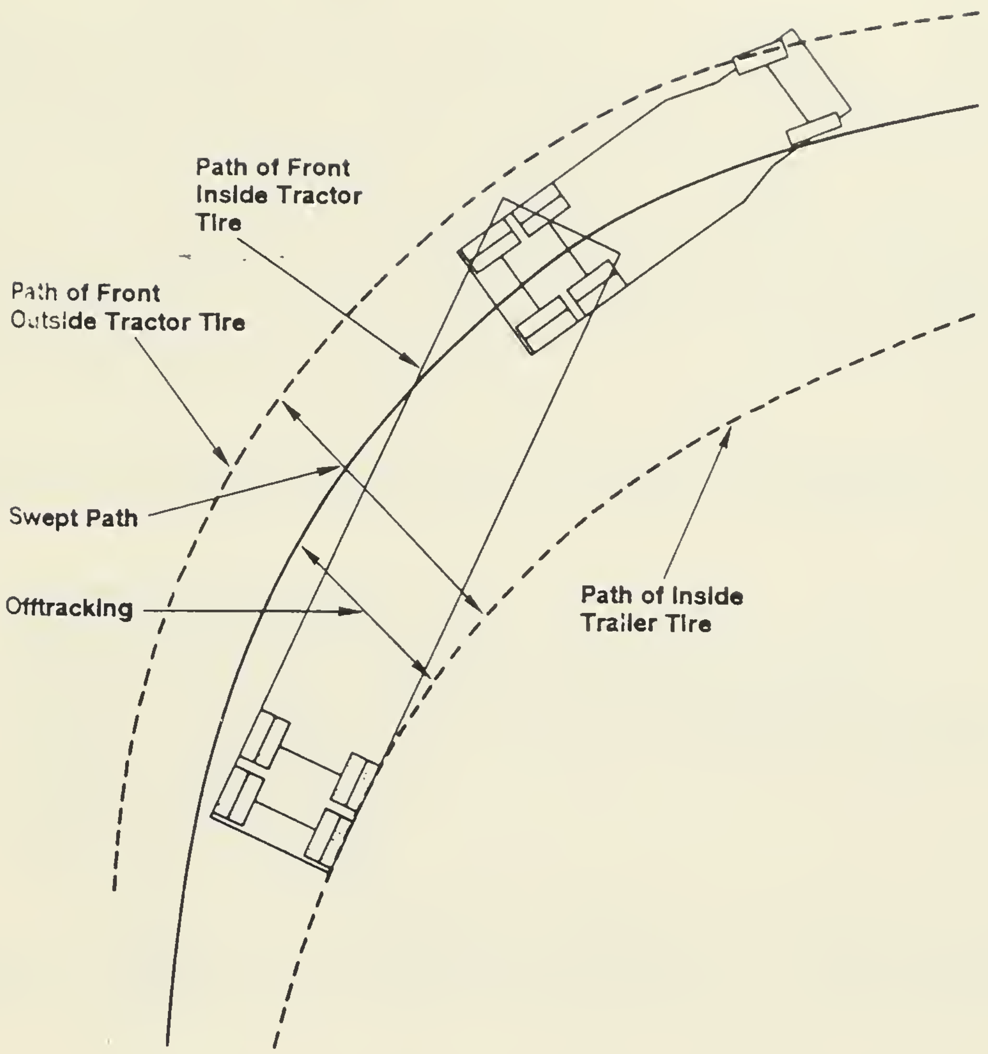

Path of Front Inside Tractor Tire
Path of Front Outside Tractor Tire
Swept Path
Offtracking
Path of Inside Trailer Tire

Figure 1. Swept path width and offtracking of a truck negotiating a 90-degree turn (caltrans).

It has been demonstrated in several studies (Truby, et al., Skinner, et al.) that offtracking is most pronounced at low speeds and on trucks with the fewest points of articulation. In terms of the relationship between tractor and semitrailer, the dimension that most affects low-speed, inward offtracking is the semitrailer wheelbase. The semitrailer wheelbase is generally measured from the kingpin to the center of the rear trailer axle or axles. By shortening this distance, offtracking is reduced and the vehicle can maneuver better on curves and intersections. Tractor wheelbase also affects offtracking but to a lesser extent.

TRUCK CONFIGURATIONS AND OFFTRACKING

Figure 2 illustrates truck configurations currently allowed on Montana's highways, configurations recommended by the WASHTO committee, and configurations that are expected to be requested by the trucking industry during Montana's 1991 legislature (the measured lengths shown are within ±1.5 ft. of the calculated lengths). Also provided in figure 2 is the offtracking distance for each configuration (where limits are applied to overall length only, worst case configurations were used to calculate offtracking. On WASHTO recommendations where overall length is not restricted, a conventional cab length was used to determine offtracking. If unusually long tractors are used, offtracking could be worse than values shown).

Offtracking values are derived from a mathematical evaluation procedure developed by the Western Highway Institute. Assumptions used for this evaluation include:

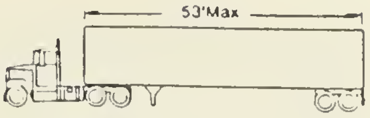
- Turning radius = 165 ft.
- Wheelbase length for conventional tractor = 18 ft.
- Wheelbase length for cab-over tractor = 13 ft.
- Distance from bumper to trailer for conventional tractor = 15 ft.
- Distance from bumper to trailer for cab-over tractor = 10 ft.
- Trailer overhang = 4 ft.
- Distance between trailers = 4 ft.
- Speed is not a factor

Note the changes in offtracking distance in relation to semitrailer length and number of articulation points on a semitrailer-trailer combination.

CURRENT MONTANA ALLOWABLE CONFIGURATIONS

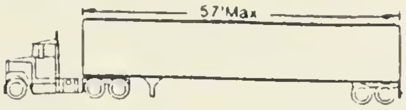
* OFF-TRACKING

1) Without Permit
All Hwys



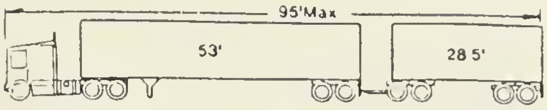
7.5'

2) With Permit
All Hwys.



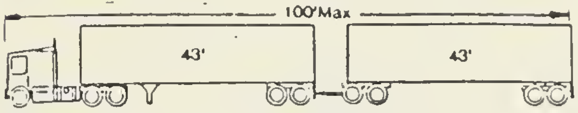
8.7'

3) With Permit
All Hwys.



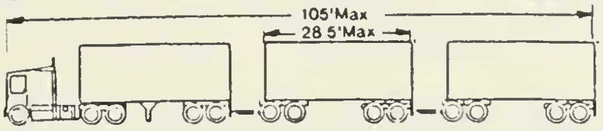
8.5'

4) With Permit
Interstate Only



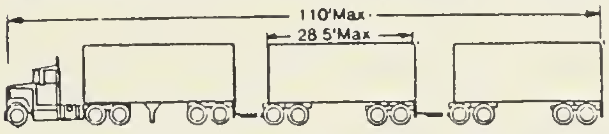
8.5'

5) With Permit
Interstate Only
Cab-Over



4.9'

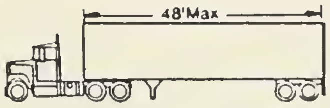
6) With Permit
Interstate Only
Conv.Cab



5.3'

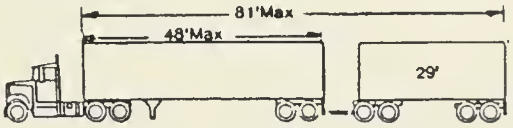
WASHTO COMMITTEE RECOMMENDATIONS

7) All Hwys.



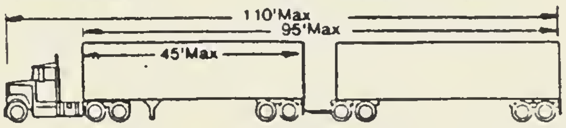
6.1'

8) All Hwys.



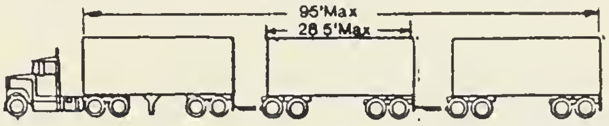
7.7'

9) Interstate Only



10.0'

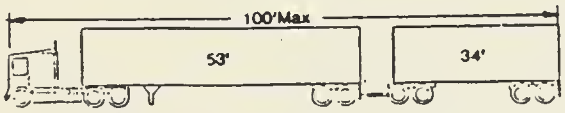
10) Interstate Only



5.3'

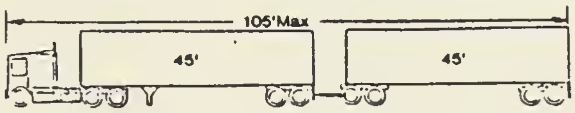
ANTICIPATED LENGTH REQUESTS

11) All Rtes.



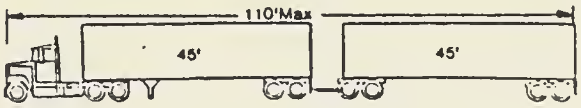
9.3'

12) Interstate Only



9.5'

13) Interstate Only



10.0'

* O-T is calculated on a 165' radius curve for each example.

Figure 2

TRUCK CONFIGURATIONS AND SWEPT PATH

As stated earlier, from the perspective of highway design, the relevant measure of offtracking is the swept path; the total lateral area required to complete a turn. Swept path values are derived using the same mathematical procedure as that used for offtracking distances. To illustrate swept path for the truck configurations in figure 2, a hypothetical, 90-degree intersection was designed. In figures 3 through 15 the shaded area represents the swept path. A turning radius of 64 ft. was used for the hypothetical intersection swept path calculations (compared to 165 ft. radius used for offtracking calculations). The reason being, a 64 ft. turning radius is a closer approximation to intersection geometrics in urban areas and geometrics found on diamond-type interchanges for right-hand turns.

Figures 16 through 19 illustrate calculated swept paths for truck configuration numbers 1, 2, 3 and 11 at the intersection of Prospect Avenue and Montana Avenue in Helena, Montana. Note the encroachment on opposing traffic lanes.

Figure 3

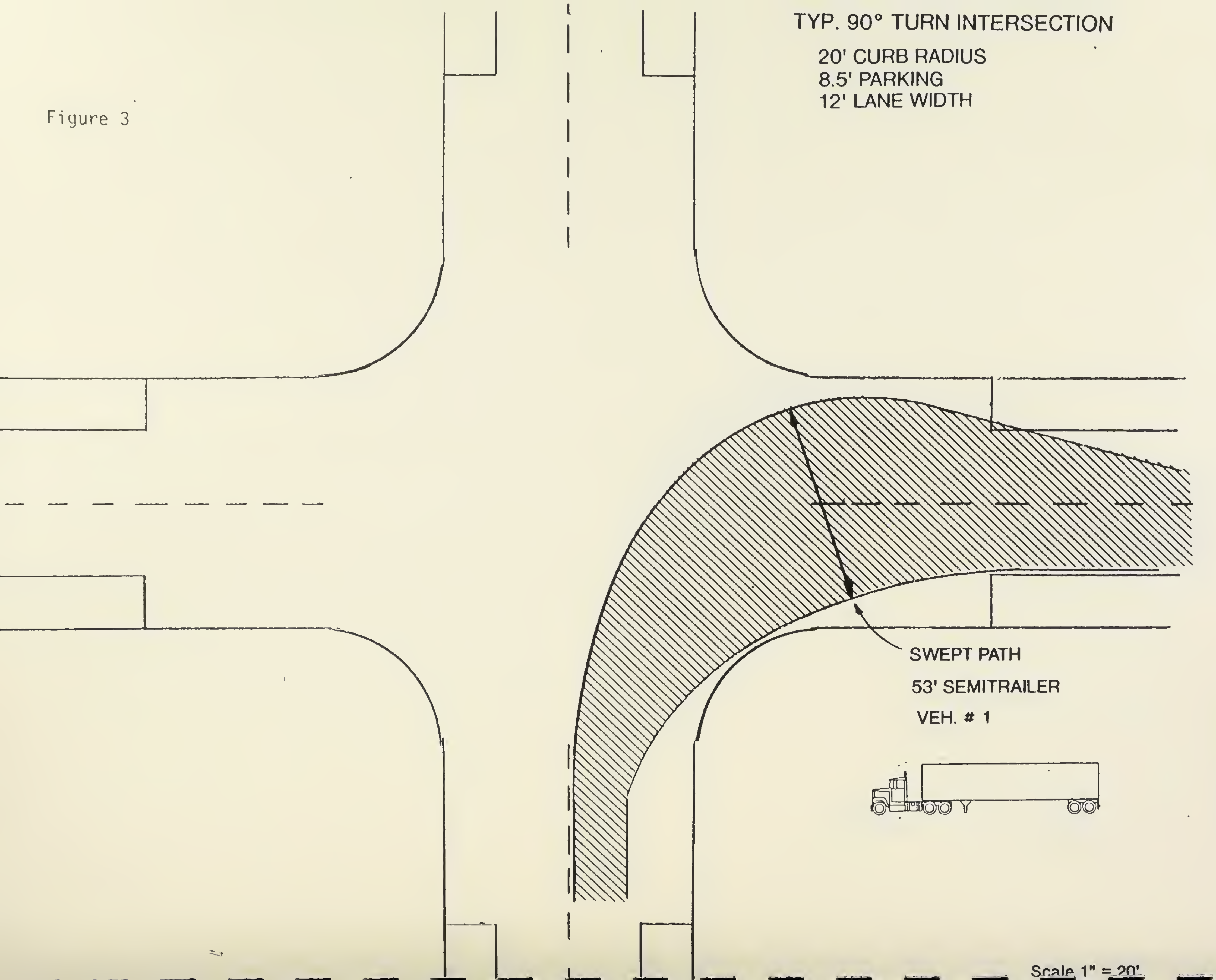


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Figure 4

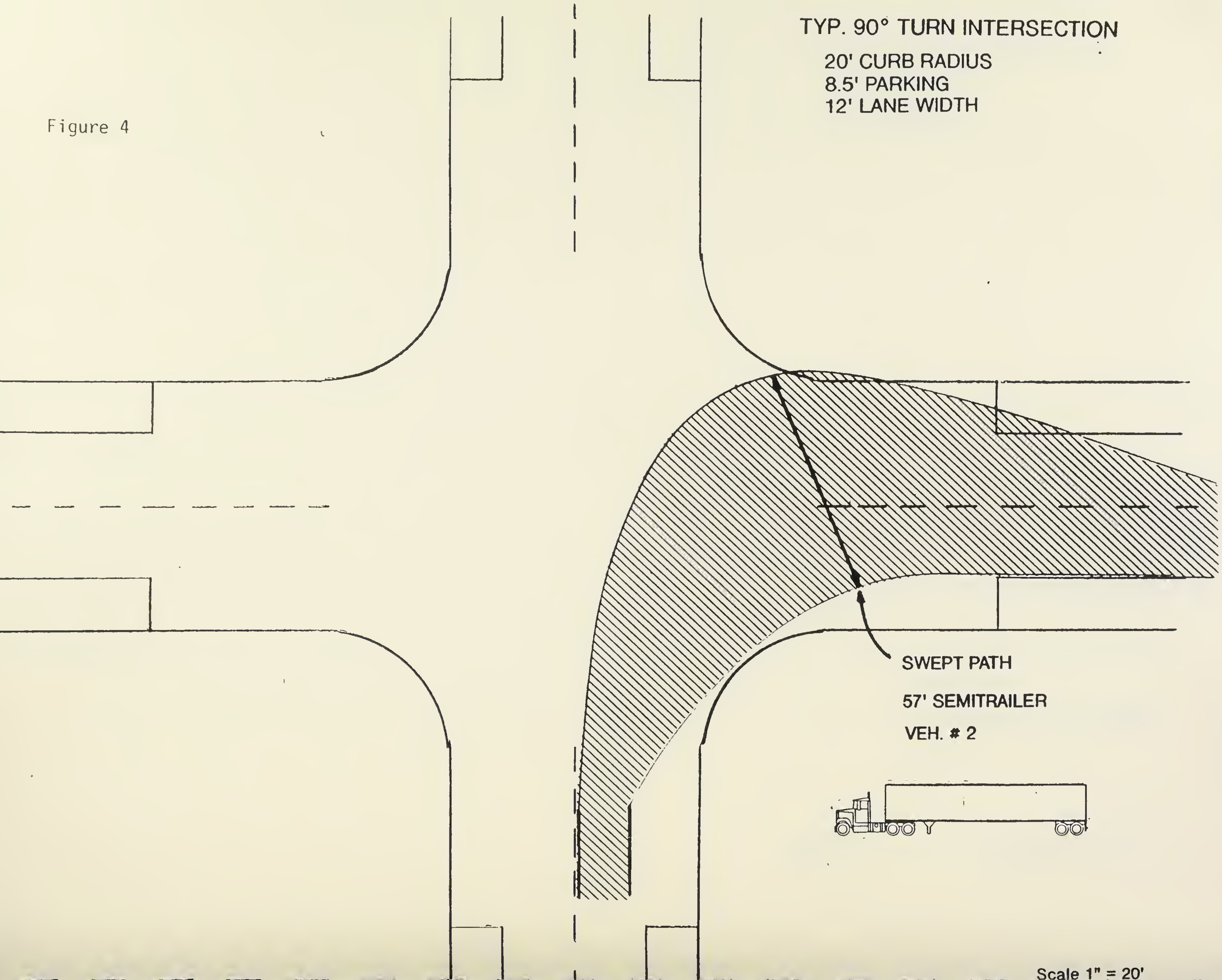

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Figure 5

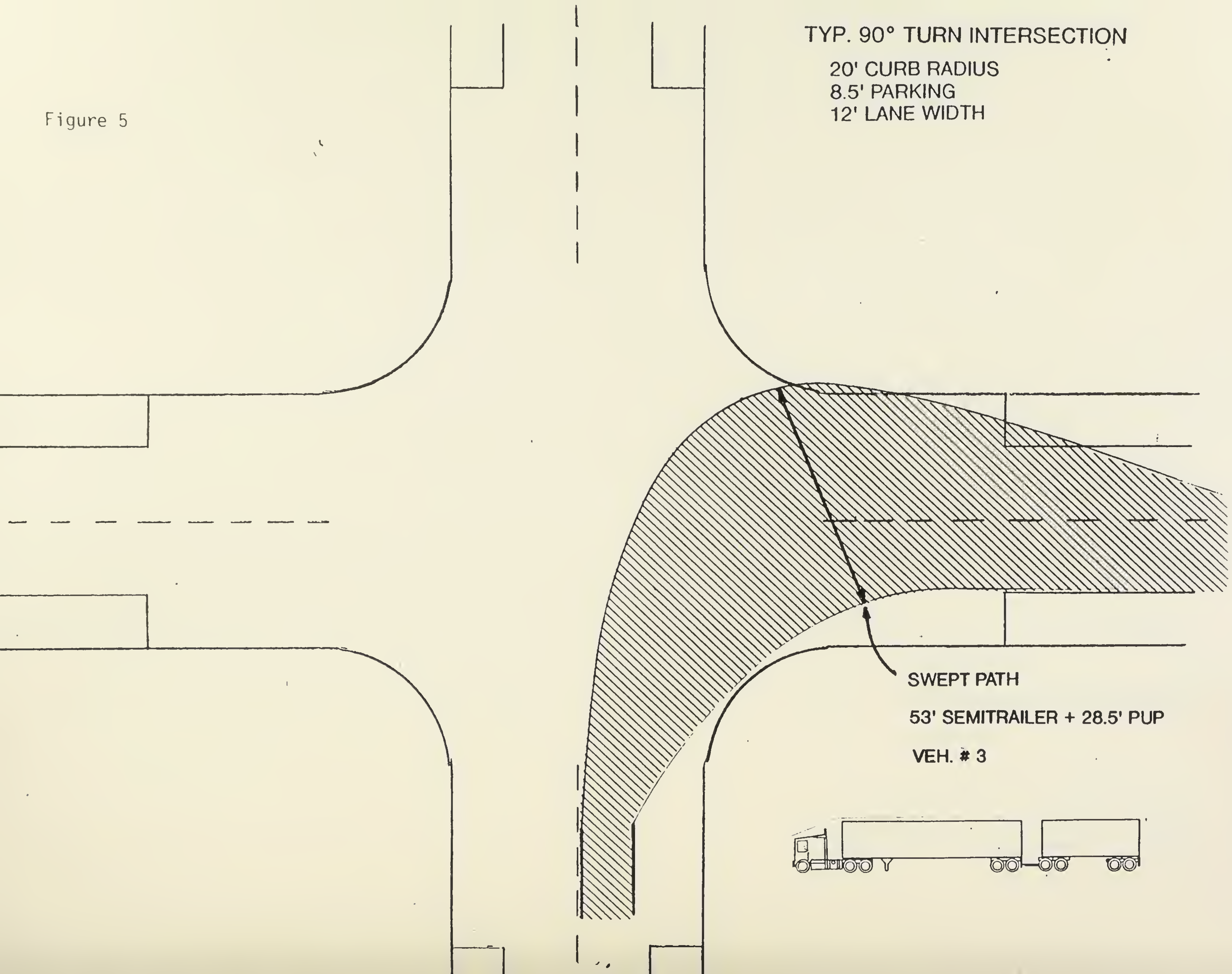
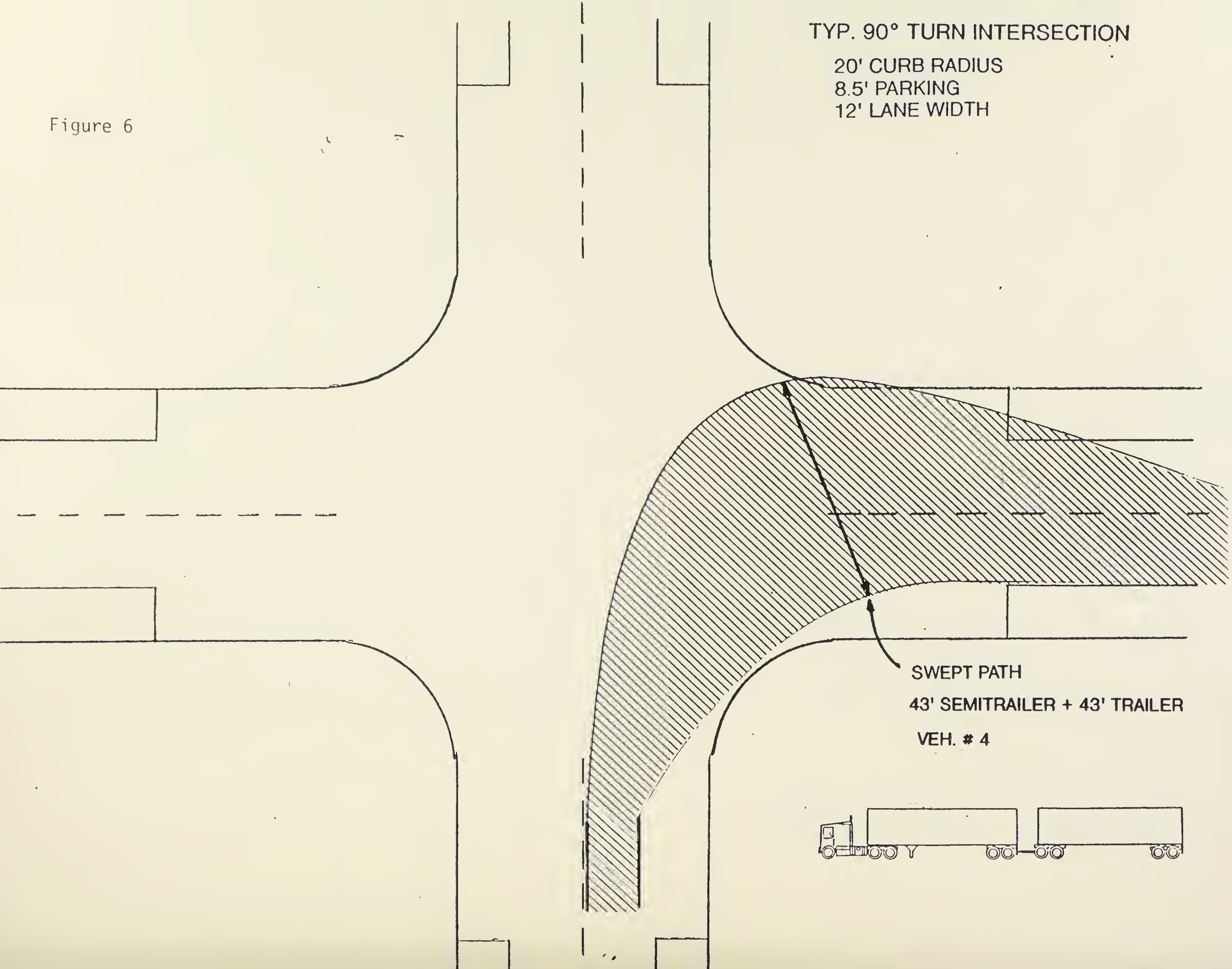

TYP. 90° TURN INTERSECTION
20' CURB RADIUS
8.5' PARKING
12' LANE WIDTH
SWEPT PATH
53' SEMITRAILER + 28.5' PUP
VEH. # 3

Figure 6



TYP. 90° TURN INTERSECTION

20' CURB RADIUS
8.5' PARKING
12' LANE WIDTH

SWEPT PATH

43' SEMITRAILER + 43' TRAILER

VEH. # 4

Figure 7

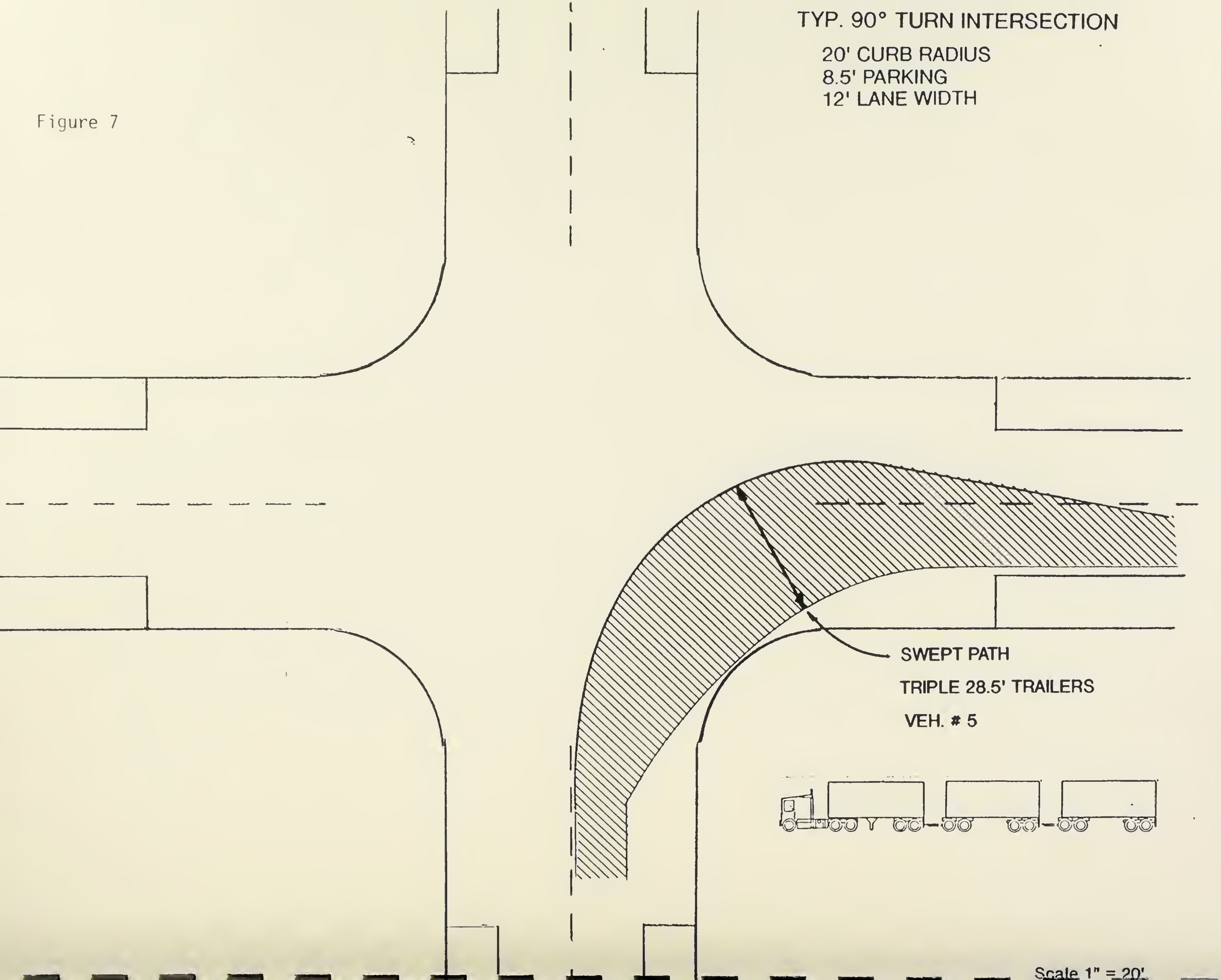
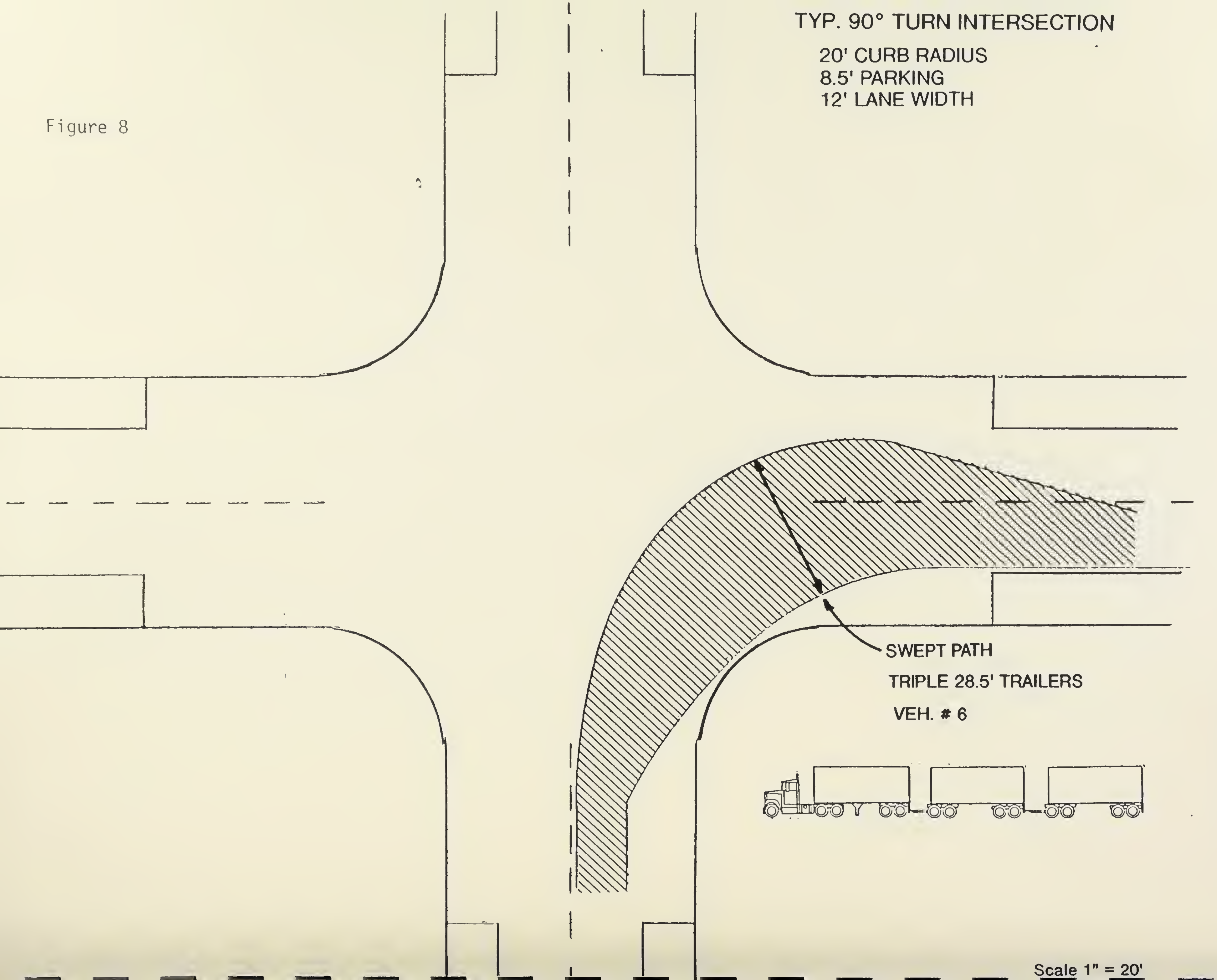

TYP. 90° TURN INTERSECTION
20' CURB RADIUS
8.5' PARKING
12' LANE WIDTH
SWEPT PATH
TRIPLE 28.5' TRAILERS
VEH. # 5
Scale 1" = 20'

Figure 8



TYP. 90° TURN INTERSECTION

20' CURB RADIUS
8.5' PARKING
12' LANE WIDTH

Scale 1" = 20'

Figure 9

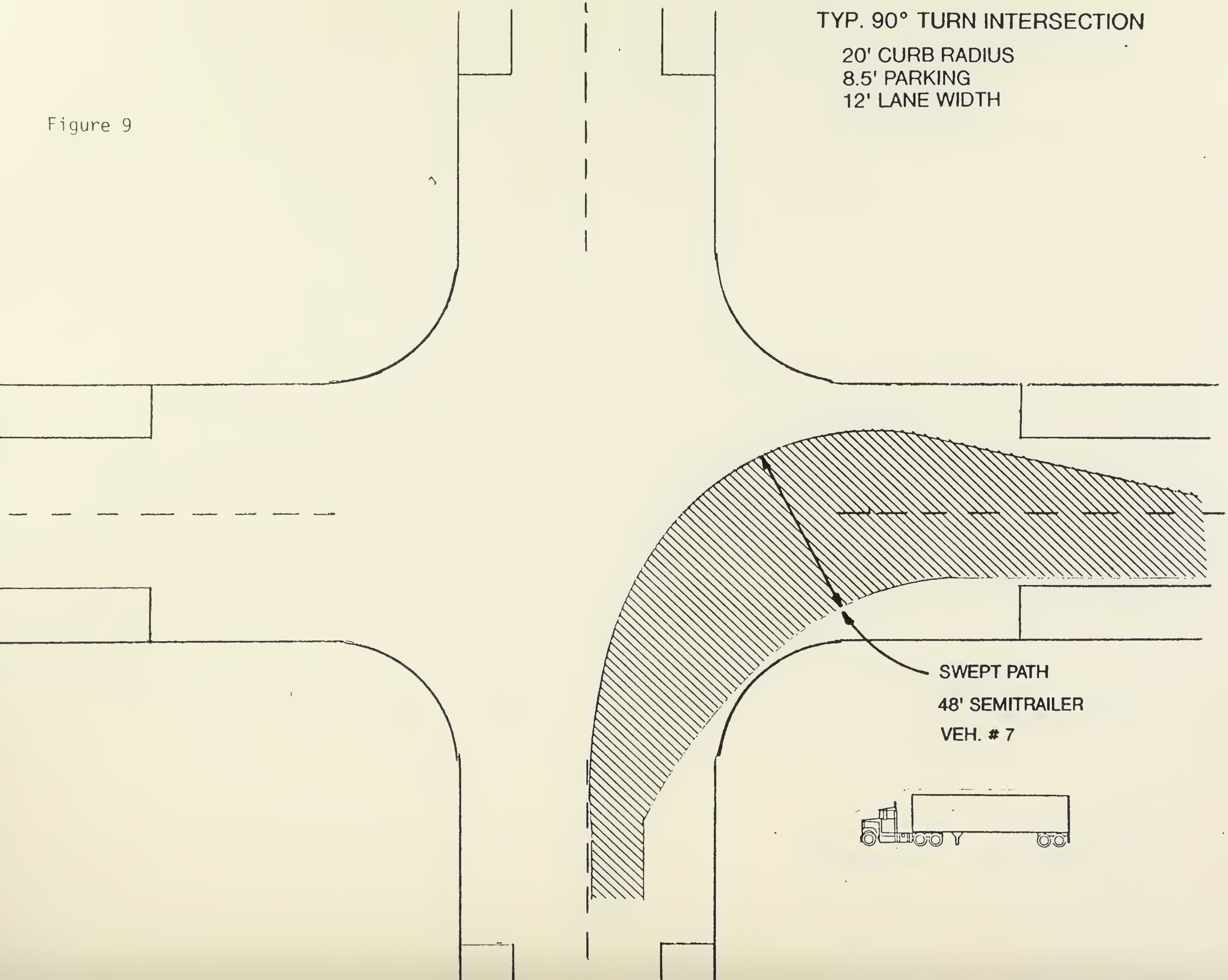


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Figure 10

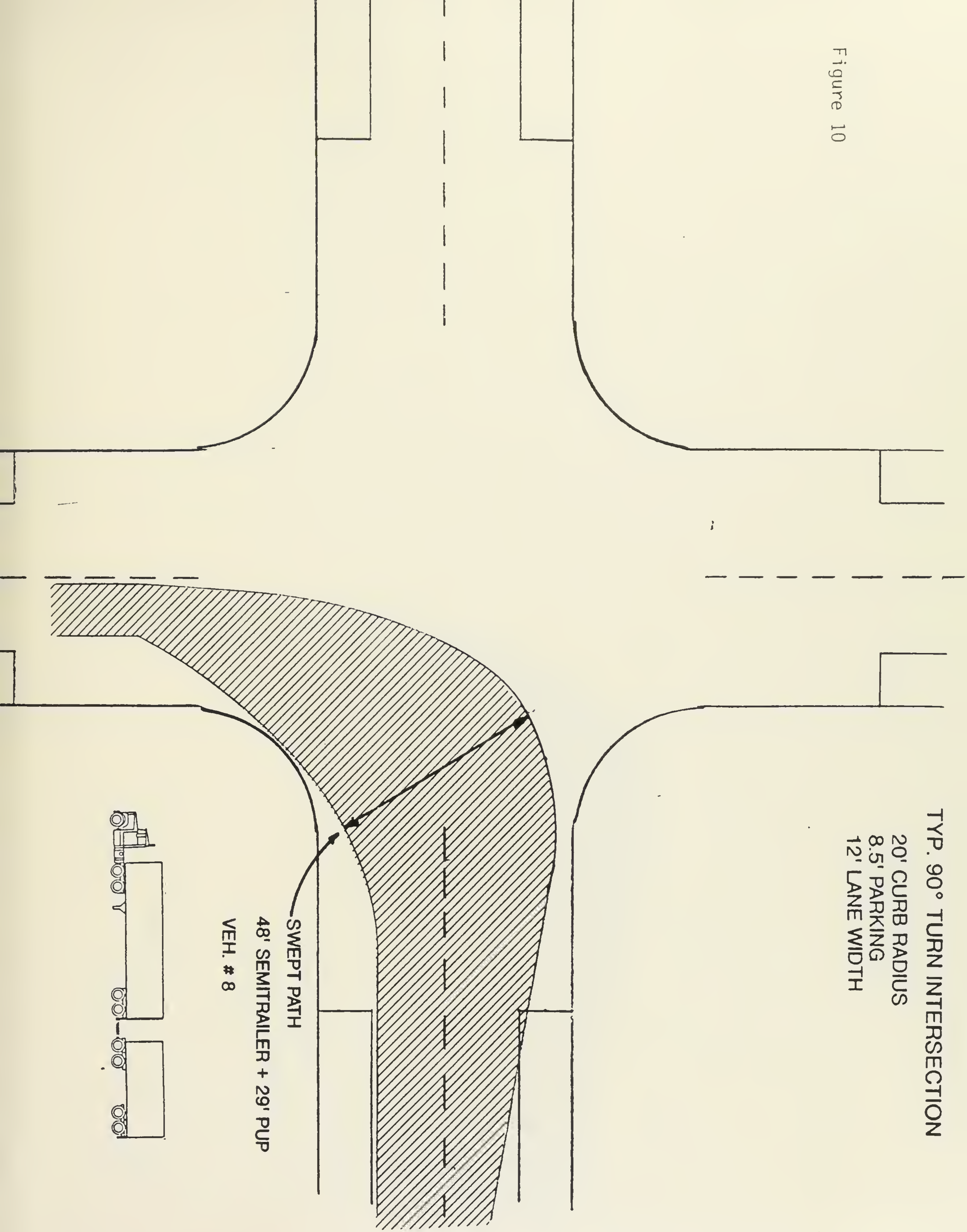
TYP. 90° TURN INTERSECTION
20' CURB RADIUS
8.5' PARKING
12' LANE WIDTH
SWEPT PATH
48' SEMITRAILER + 29' PUP
VEH. # 8

Figure 11

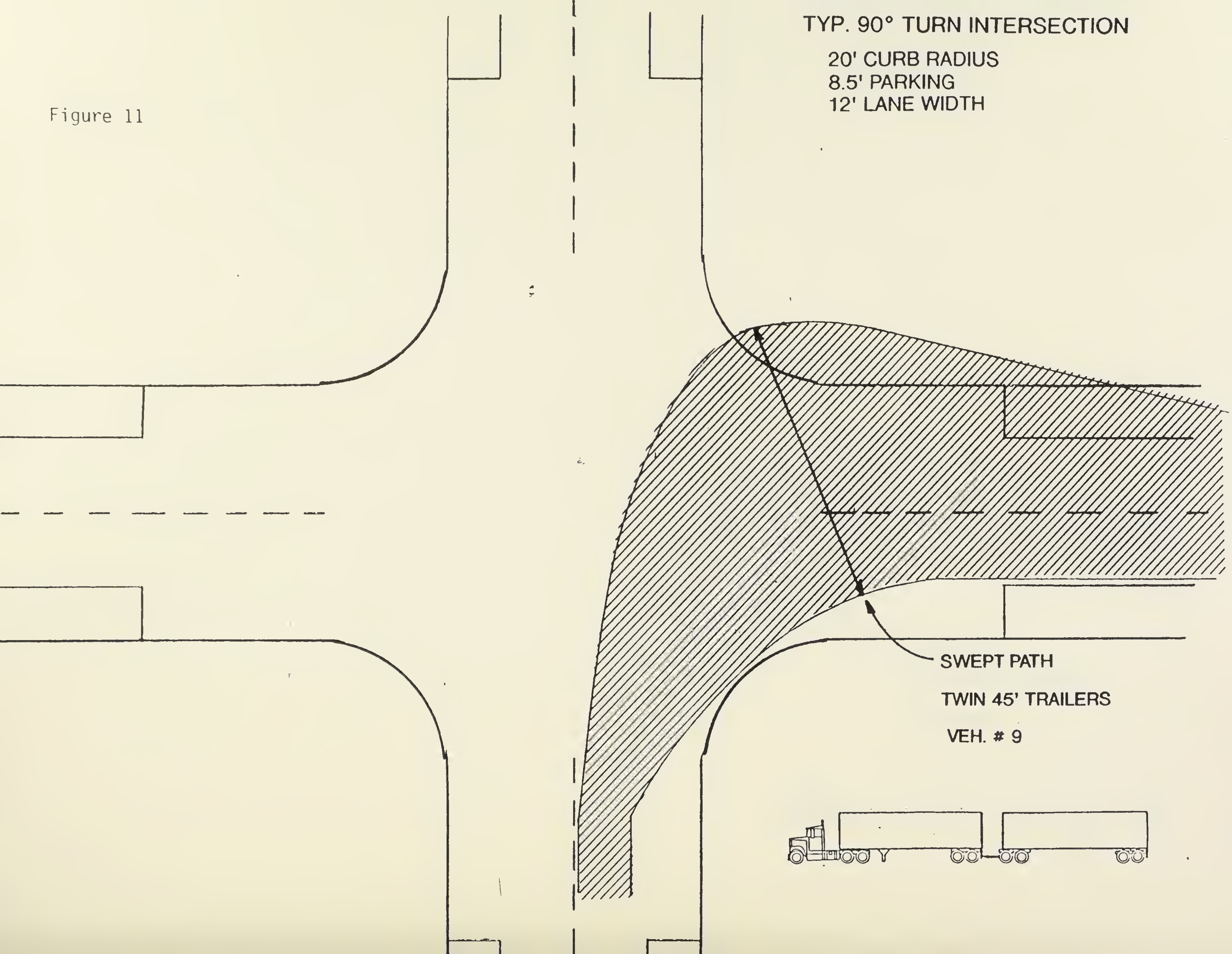

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Figure 12

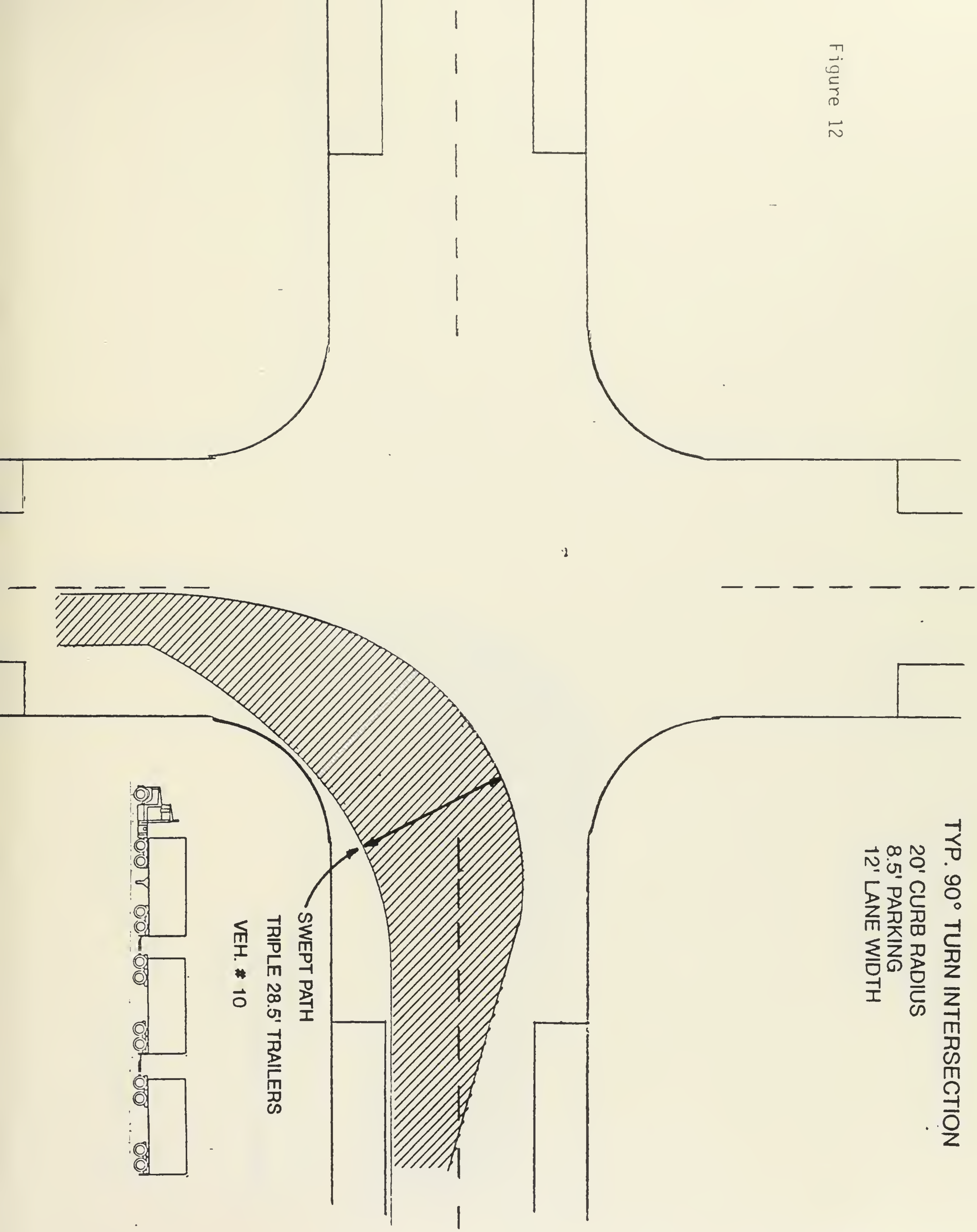

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Figure 13

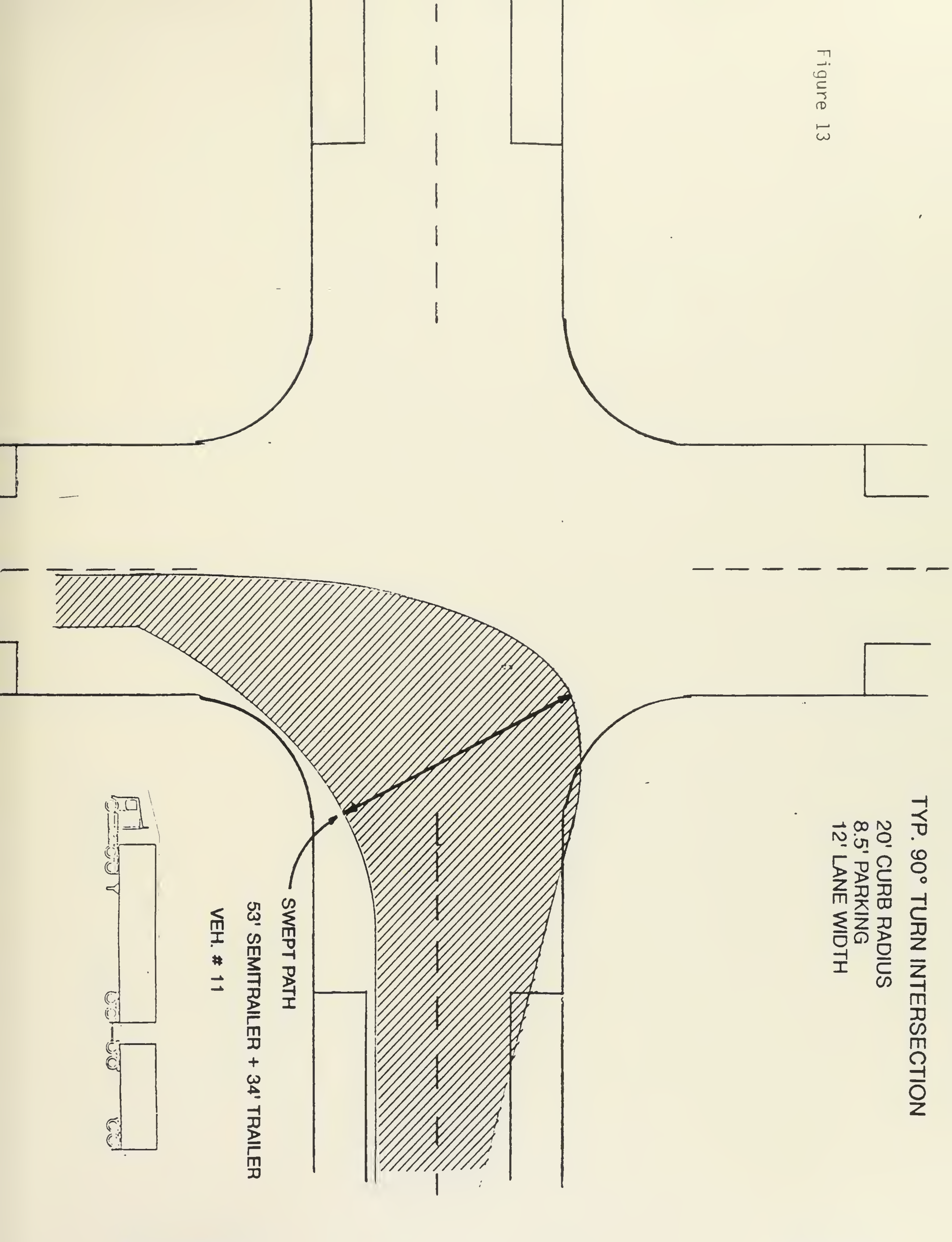

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Figure 14

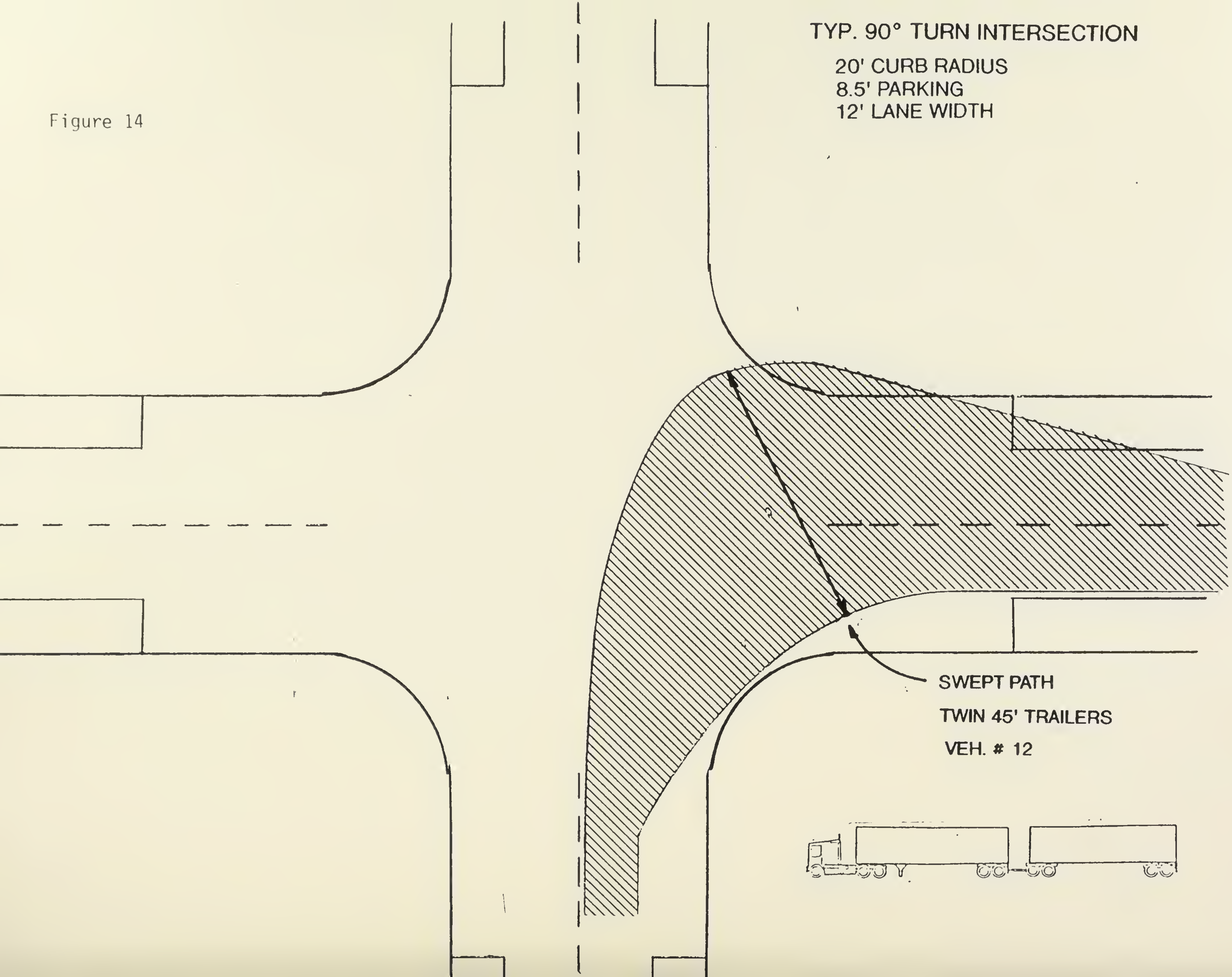

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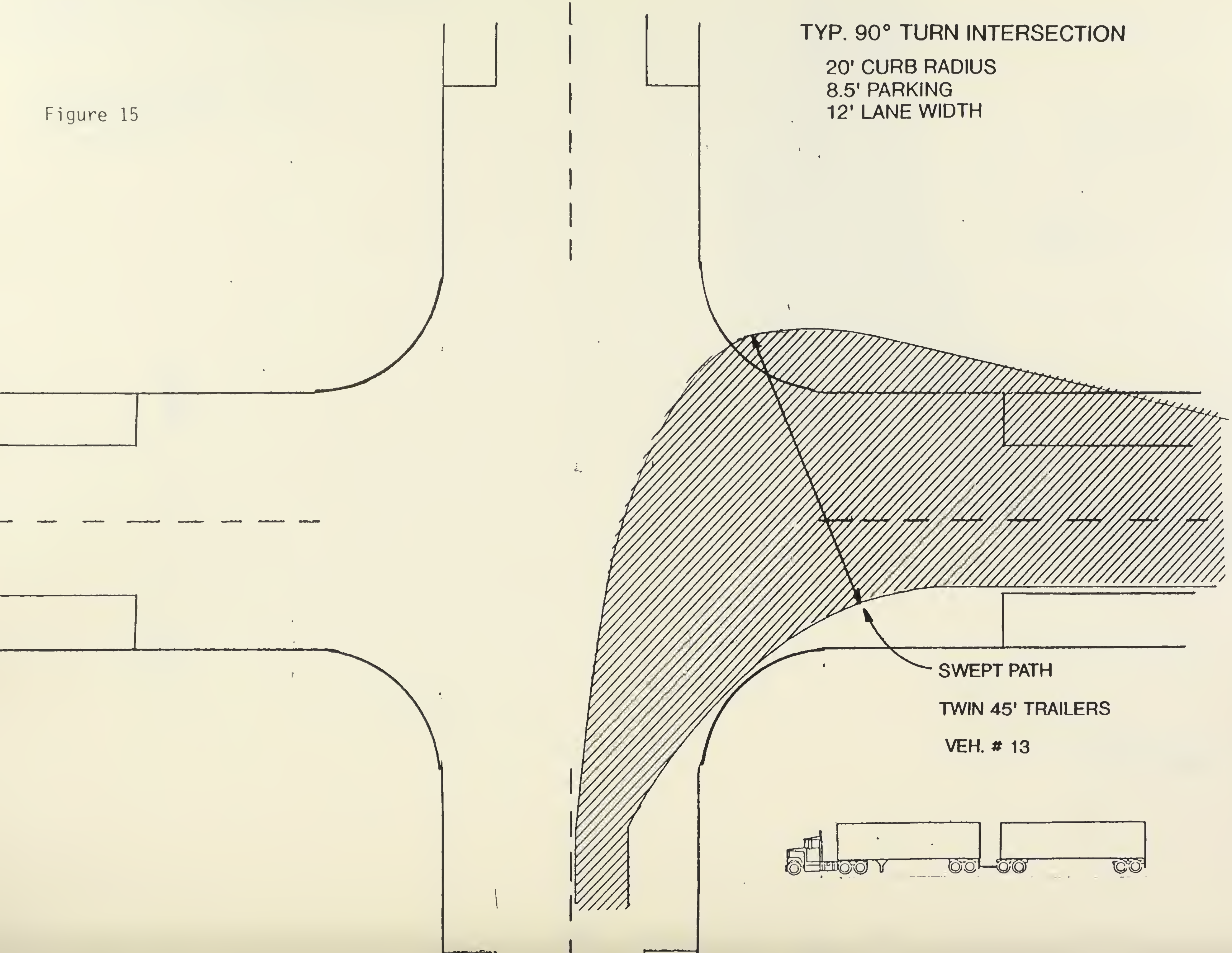
Figure 15


TYP. 90° TURN INTERSECTION
20' CURB RADIUS
8.5' PARKING
12' LANE WIDTH
SWEPT PATH
TWIN 45' TRAILERS
VEH. # 13

INTERSECTION OF PROSPECT AVE. AND MONTANA AVE. IN HELENA

TYP. 90° TURN INTERSECTION
24' NE CURB RADIUS
8' PARKING ON WEST LEG ONLY
12' LANE WIDTH

Figure 16

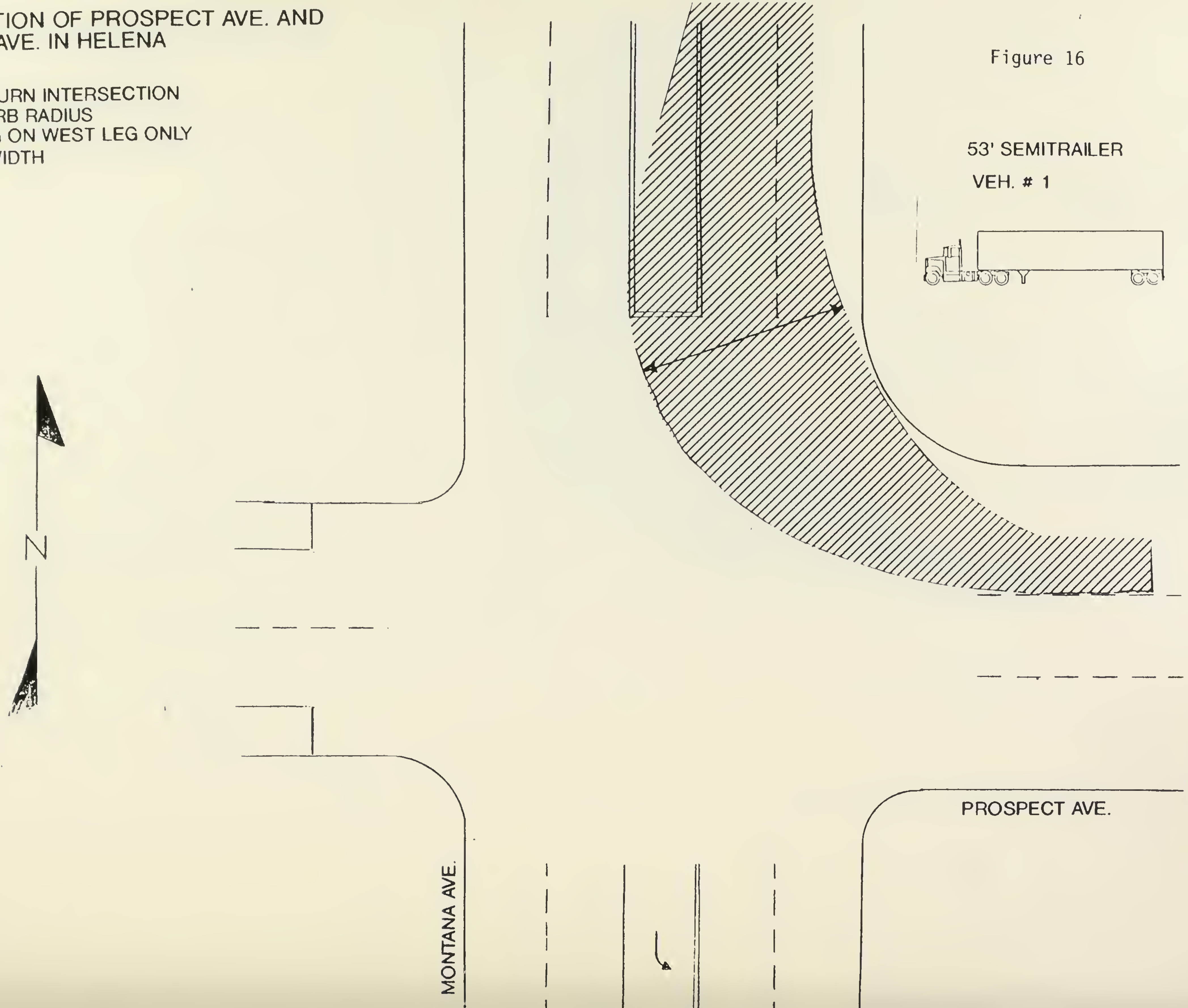


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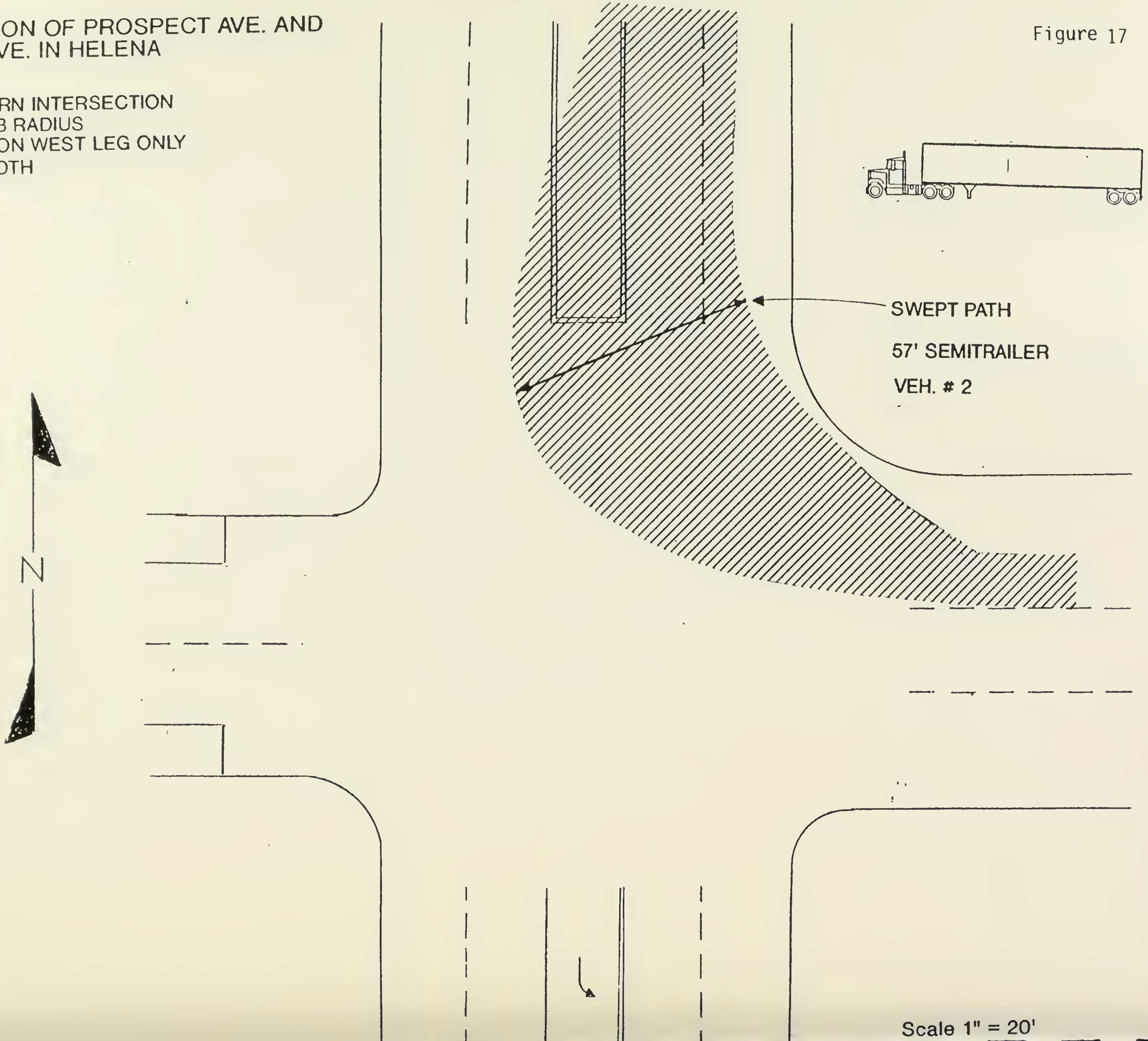
Figure 17

INTERSECTION OF PROSPECT AVE. AND MONTANA AVE. IN HELENA

TYP. 90° TURN INTERSECTION
24' NE CURB RADIUS
8' PARKING ON WEST LEG ONLY
12' LANE WIDTH



Scale 1" = 20'

09/14/90

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Figure 18

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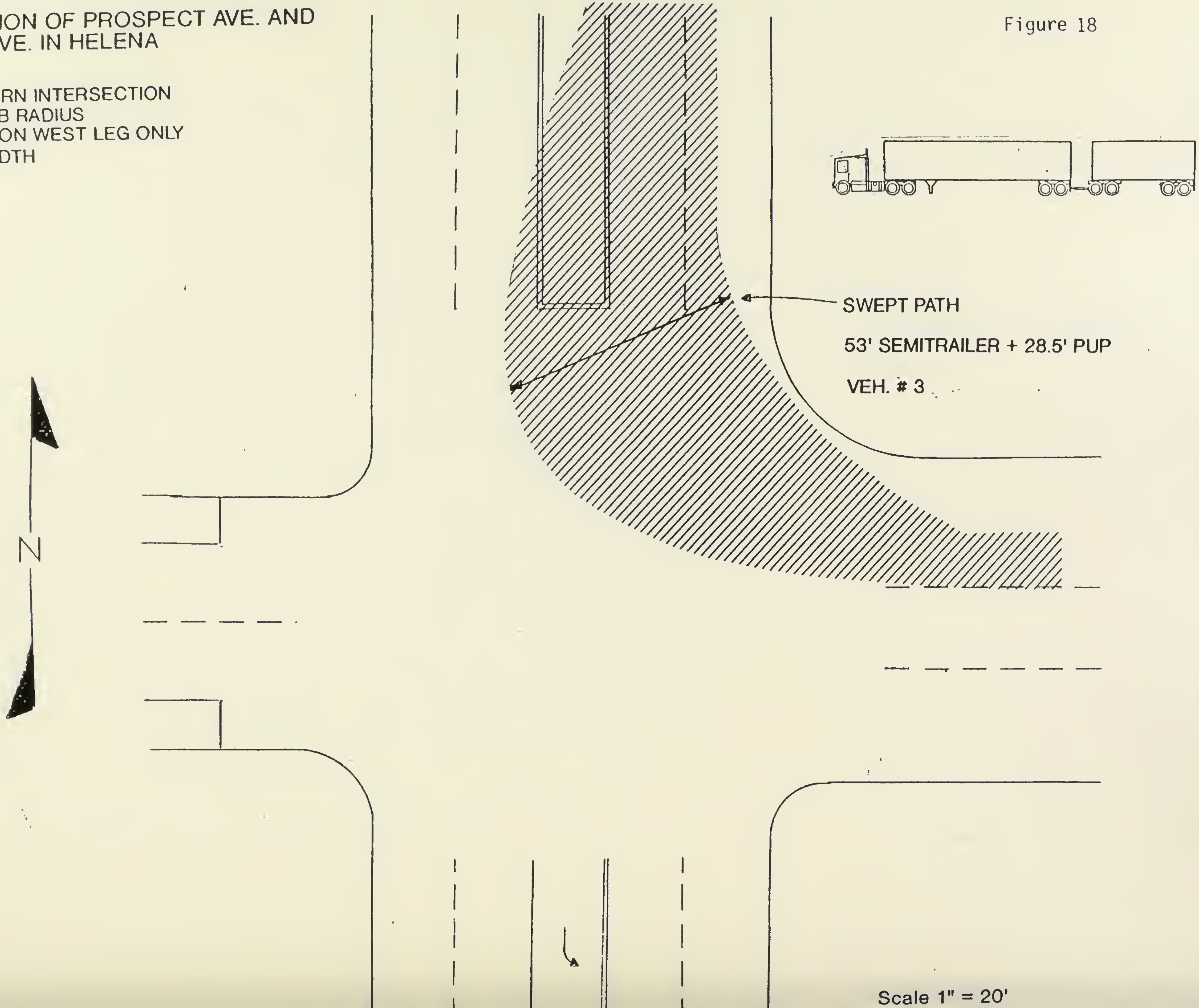
INTERSECTION OF PROSPECT AVE. AND MONTANA AVE. IN HELENA

TYP. 90° TURN INTERSECTION
24' NE CURB RADIUS
8' PARKING ON WEST LEG ONLY
12' LANE WIDTH



53' SEMITRAILER + 28.5' PUP

VEH. # 3

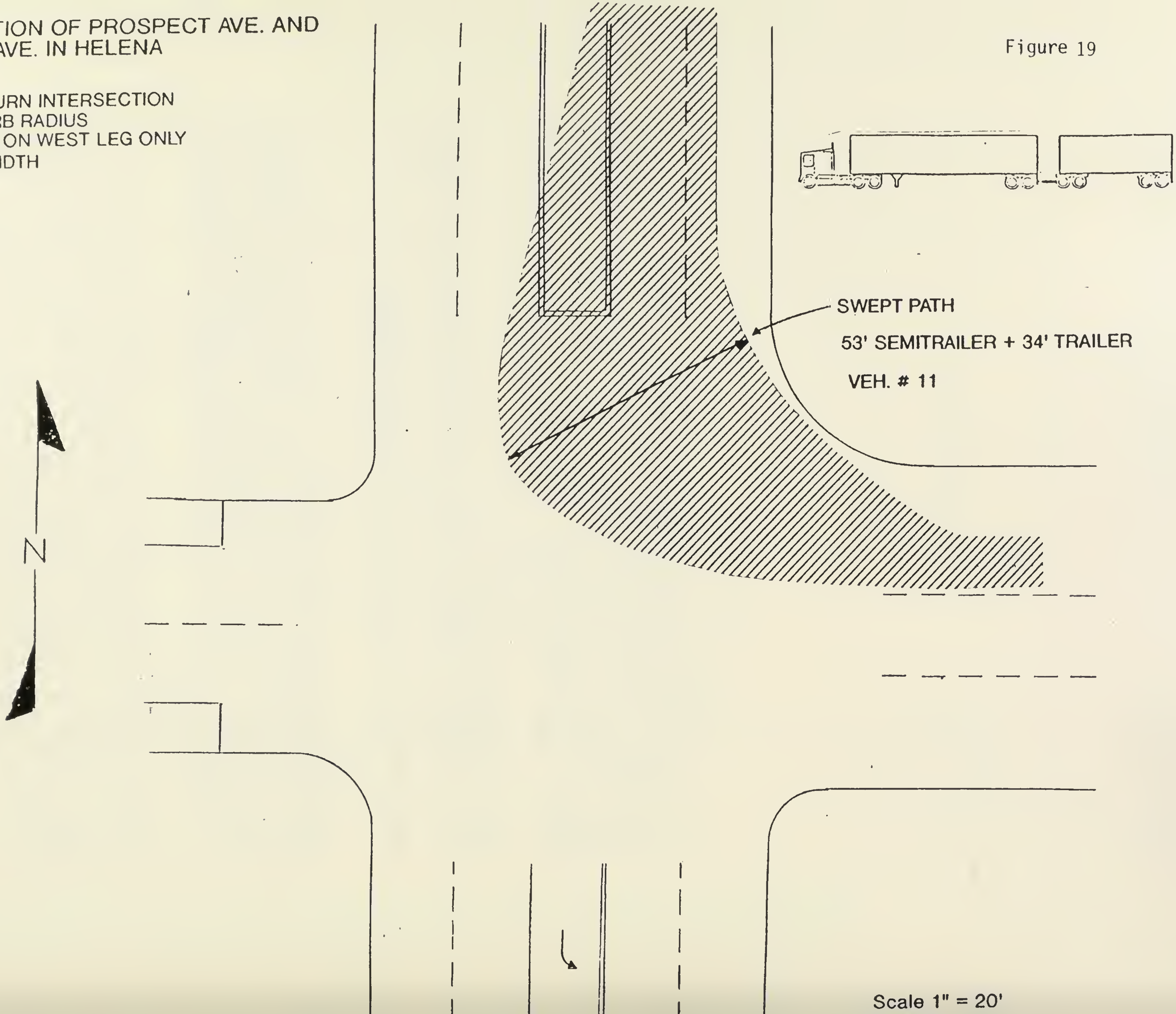
Scale 1" = 20'

MS:0:cg:228W-21

Figure 19

INTERSECTION OF PROSPECT AVE. AND MONTANA AVE. IN HELENA

TYP. 90° TURN INTERSECTION
24' NE CURB RADIUS
8' PARKING ON WEST LEG ONLY
12' LANE WIDTH



Scale 1" = 20'

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DESIGN CRITERIA AND ALLOWABLE CONFIGURATIONS

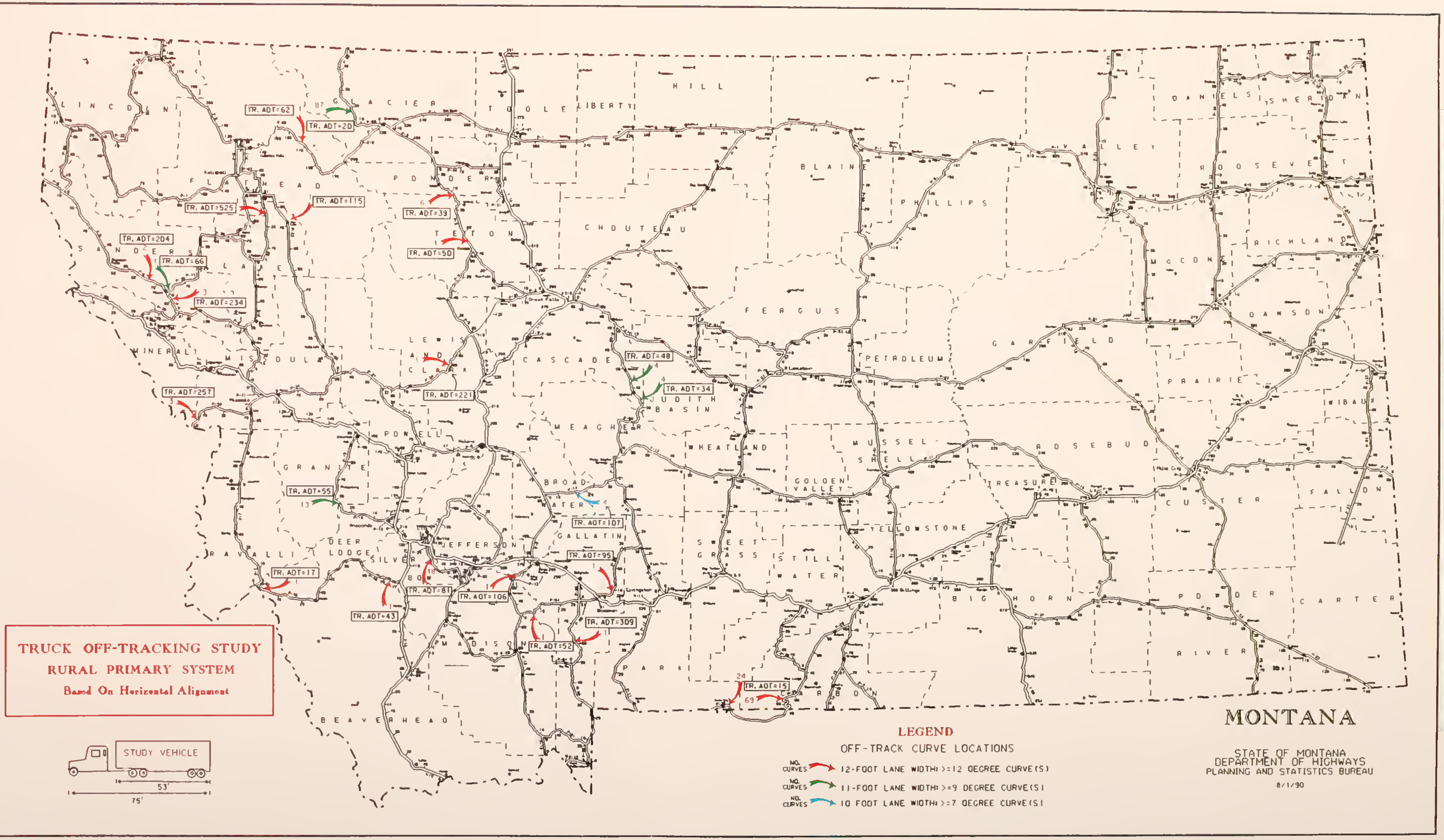
Prior to 1982, where right-of-way permitted, Montana's highways were designed to accommodate tractor-semitrailer combinations with an overall wheelbase of 50 ft. (WB-50; 37 ft. semitrailer). In 1982, the Surface Transportation Assistance Act (STAA) mandated the legal operation of longer tractor-semitrailer combinations on designated truck routes within each state. The total allowable length for a STAA vehicle is 70 ft. (C-70; 48 ft. semitrailer). In 1982, Montana adopted the C-70 dimensions as the standard design criteria for roads where trucks are allowed (Copenhaver).

At the present time, Montana allows tractor-semitrailer combinations on all Interstate, Primary, and Secondary System highways with semitrailer lengths of 53 ft. and 57 ft. Although the 57 ft. semitrailer is allowed by special permit only, the 53 ft. semitrailer requires no special permit. When compared to STAA semitrailer lengths (48 ft.), and WASHTO recommended semitrailer lengths (Figure 2), Montana's 53 ft. semitrailer length stands out as the most liberal.

PROBLEMS RELATED TO OFFTRACKING AND MITIGATING MEASURES

Specific problems associated with truck offtracking include: Opposite lane encroachment, pavement erosion, interference with normal traffic operation, damage to roadside appurtenances (curbs, signs, guardrails, etc.), and pedestrian safety.

Figure 20 shows locations where offtracking problems could occur on Montana's rural Primary routes. Observations were made at a number of these locations that led to the conclusion offtracking on most rural Primary routes is a function of driver skill rather than substandard road design. The most critical offtracking problems are on diamond-type interchanges and in Montana's urban areas and smaller cities (Morgan). It is here trucks are most likely to encounter 90-degree turns with restrictive geometrics and encroach on opposing traffic.



TRUCK OFF-TRACKING STUDY

RURAL PRIMARY SYSTEM

Based On Horizontal Alignment

LEGEND

OFF-TRACK CURVE LOCATIONS

- NO. CURVES 🟥 12-FOOT LANE WIDTH: >=12 DEGREE CURVE(S)
- NO. CURVES 🟩 11-FOOT LANE WIDTH: >=9 DEGREE CURVE(S)
- NO. CURVES 🟦 10 FOOT LANE WIDTH: >=7 DEGREE CURVE(S)

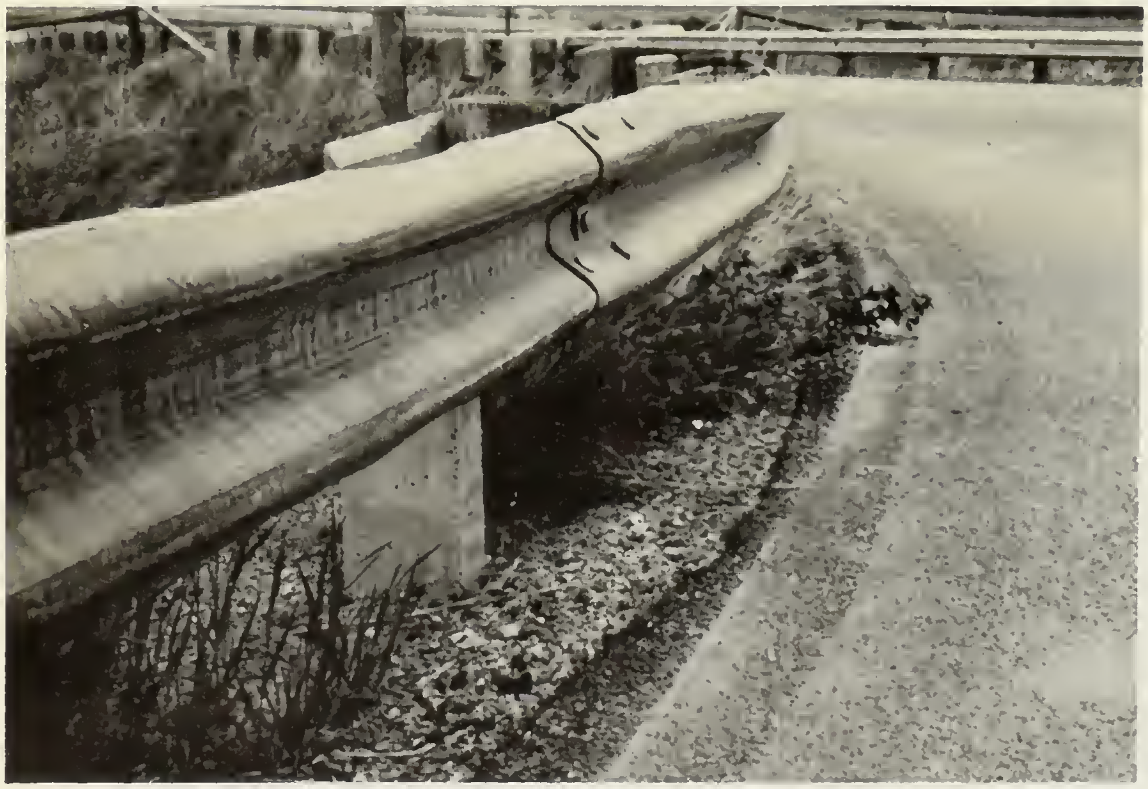
MONTANA

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
PLANNING AND STATISTICS BUREAU
8/1/90

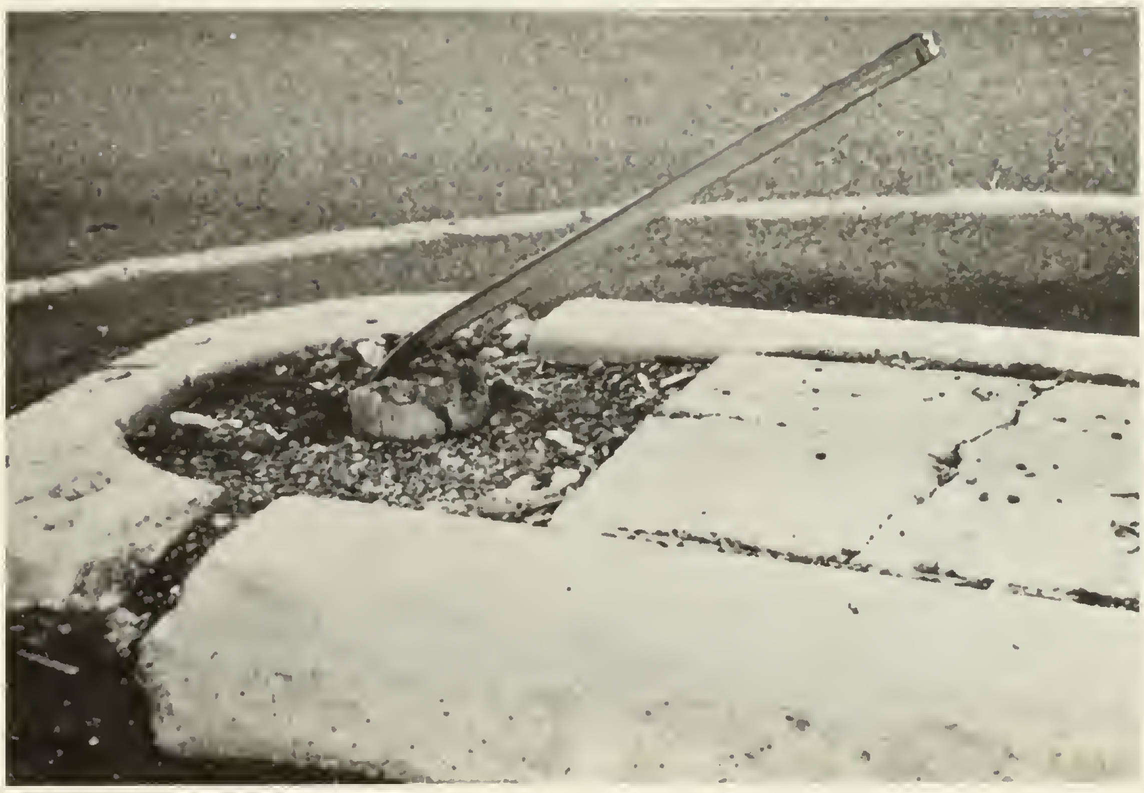
Figure 20

There are 190 diamond or half diamond-type interchanges on Montana's Interstate System. At least 94% of the interchanges were built prior to 1983 using WB-50 design criteria. As a result, the majority of interchanges in Montana are now of substandard design for STAA vehicle configurations and other longer configurations currently allowed on all Montana highways. Because of this, a chronic and costly maintenance problem currently exists.

Using a random sample of 27 diamond-type interchanges, it was found that 20 (74%) of those interchanges had damaged guardrails, cattleguards, reflectors, or a combination of the three. It cannot be assumed that all damage was caused by truck offtracking because no trucks were actually observed at the interchanges, however, the damage was carefully inspected and only damage characteristic to offtracking was recorded. The following photographs show a number of common offtracking problems that occur on interchanges and in urban areas.

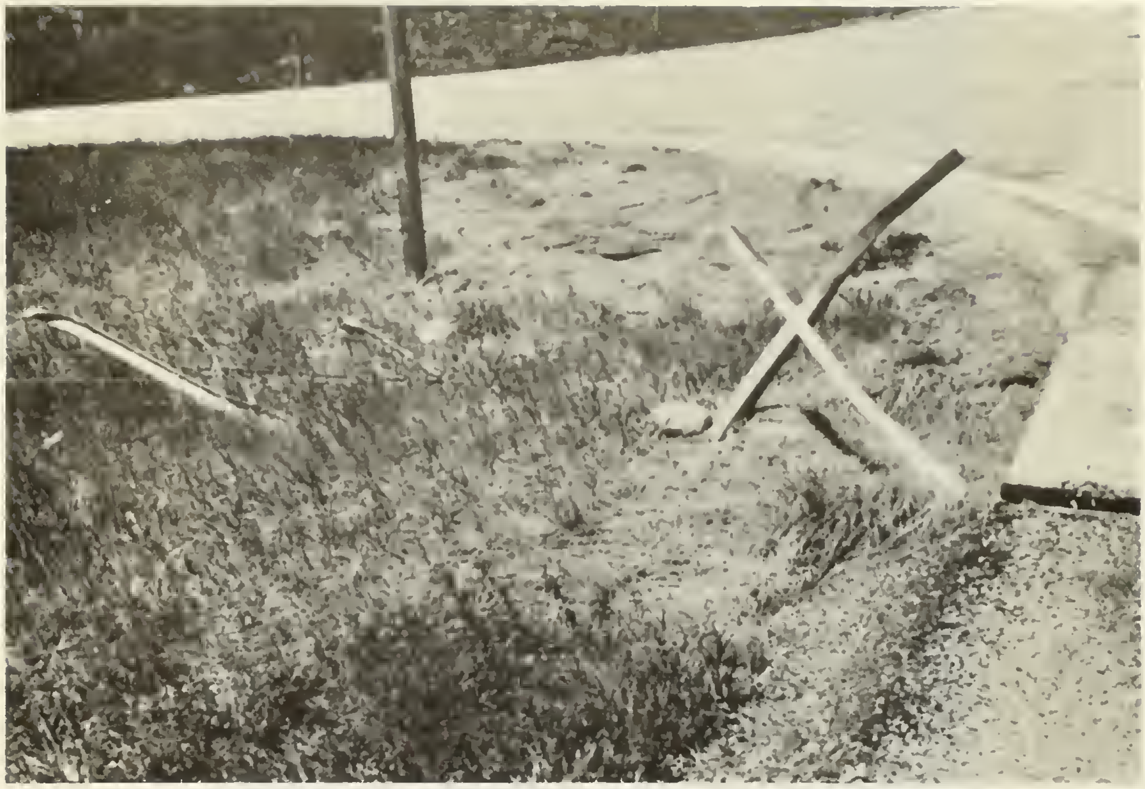


Interchange guardrail that has been
damaged, replaced, and damaged again

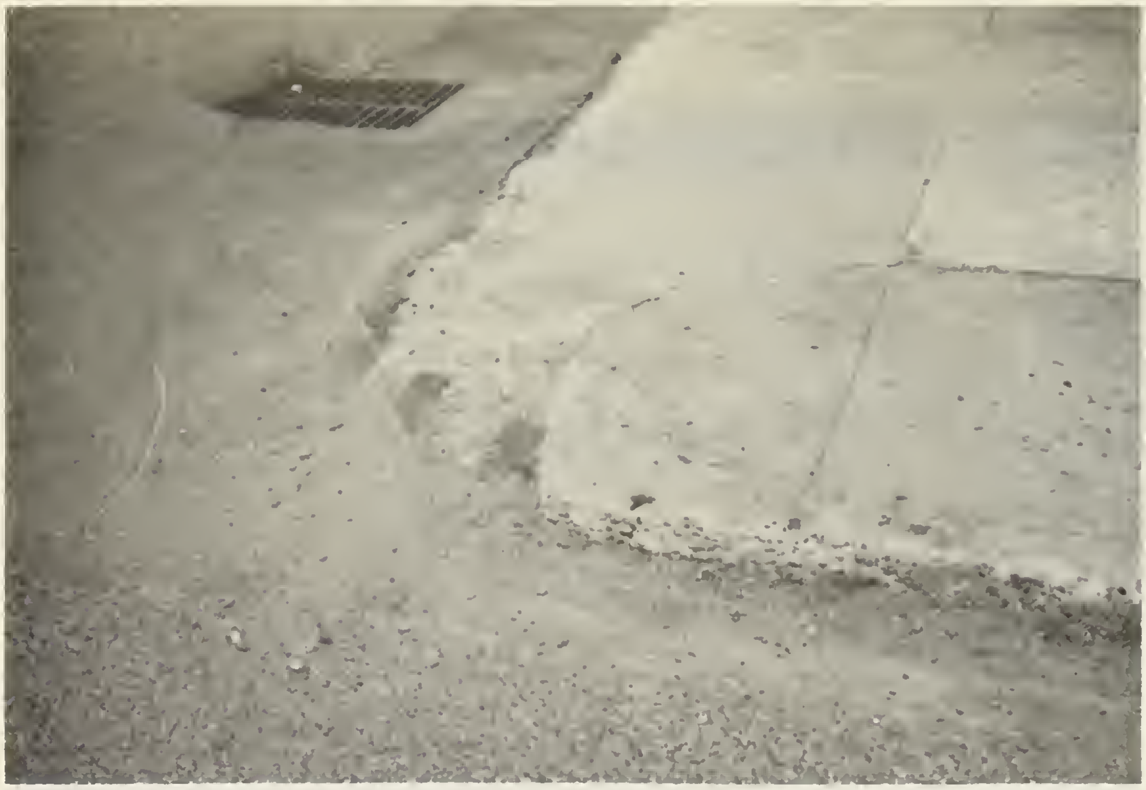


Median, reflector, and sign post damage

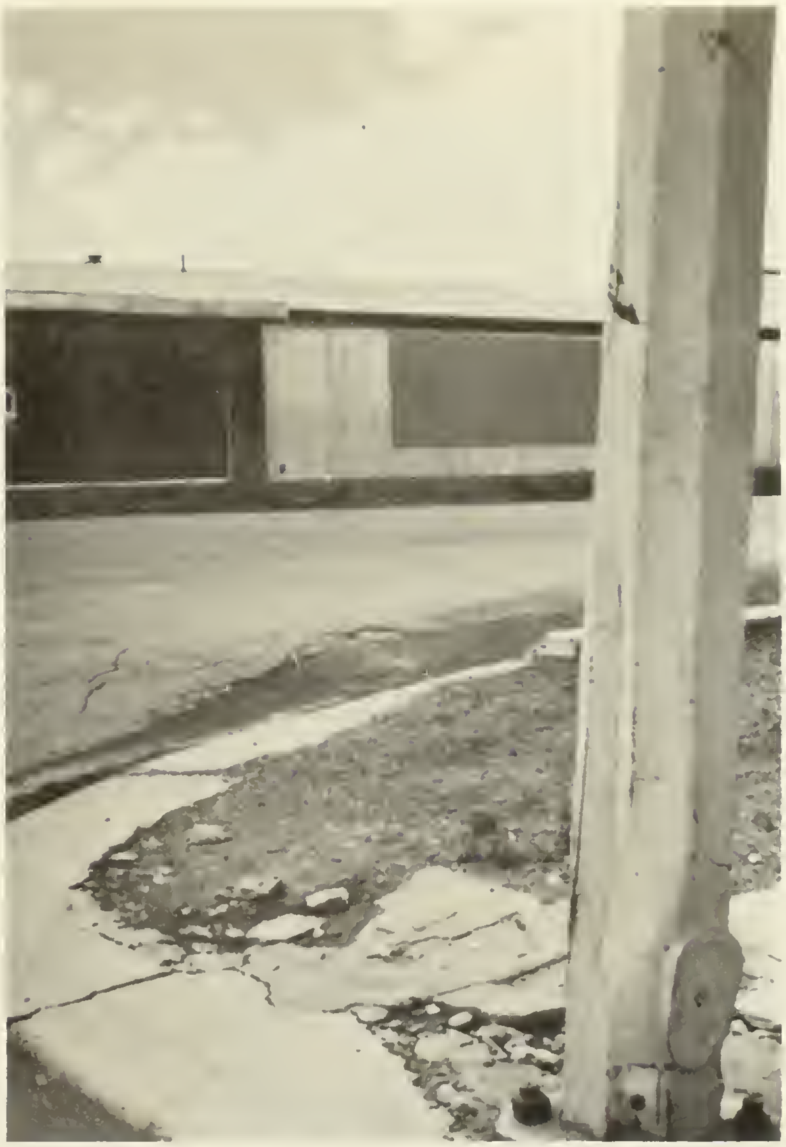
Pavement erosion



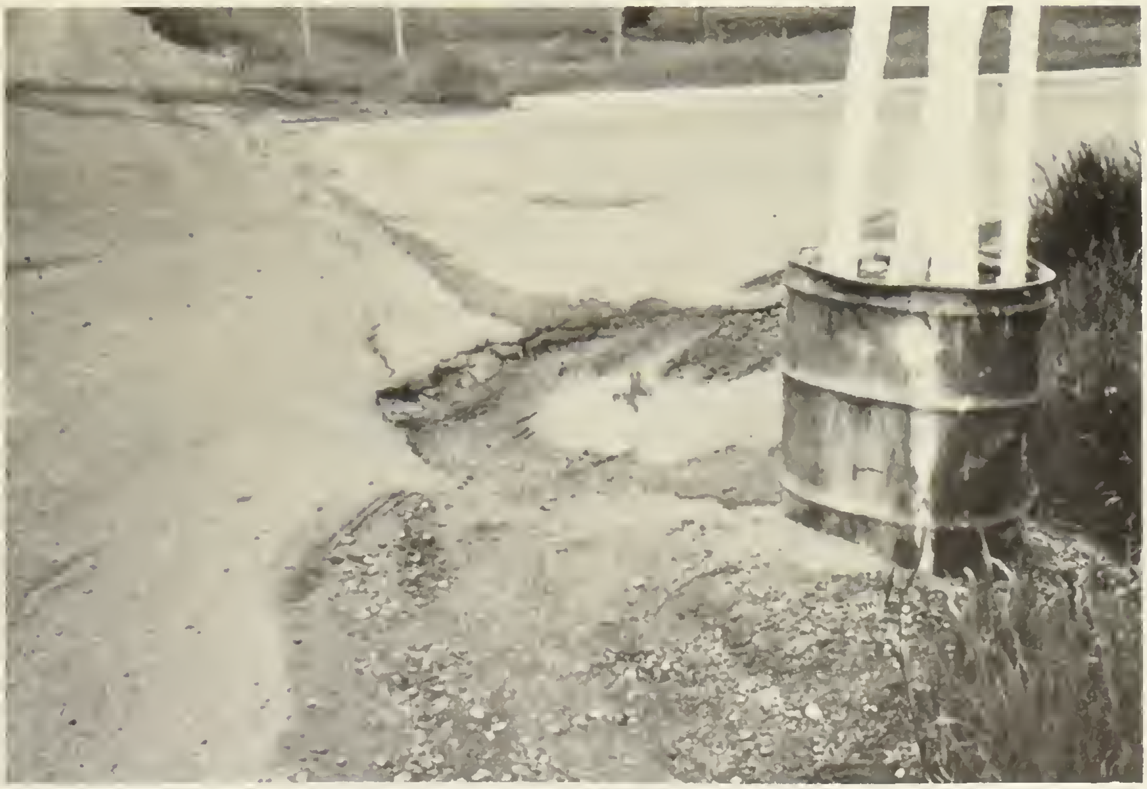
Cattleguard damage



Curb erosion



Curb and street light damage



Temporary solution to chronic offtracking problem

On Montana's Federal Aid Primary System, there is a total of seventy-four 90-degree turns, or junctions with other Primary routes, located in 50 cities (Kovich). To negotiate a 90-degree turn to the right in an urban setting, the C-70 design vehicle requires a 60 ft. curb radius with parking prohibited for 50 ft. beyond the curb return on the cross-street. This assumes that both the intersecting streets have 8 ft. shoulders; the vehicle starts the turn from the right 12 ft. lane; the vehicle crowds the left lane line; the turn is completed in the right 12 ft. lane of the cross-street; and the available shoulder is used. Montana's present city curb radii range from 15 ft. to 25 ft. with larger radii used when trucks warrant and right-of-way allows. However, there are very few locations where enough right-of-way is available to accommodate a 60 ft. radius curb return. By the same token, there are very few, if any, presently built to these dimensions (Morgan).

Figure 21 illustrates a scenario of a tractor-semitrailer combination making a right-hand turn in an intersection with restrictive geometrics, cross-traffic, and roadside appurtenances.

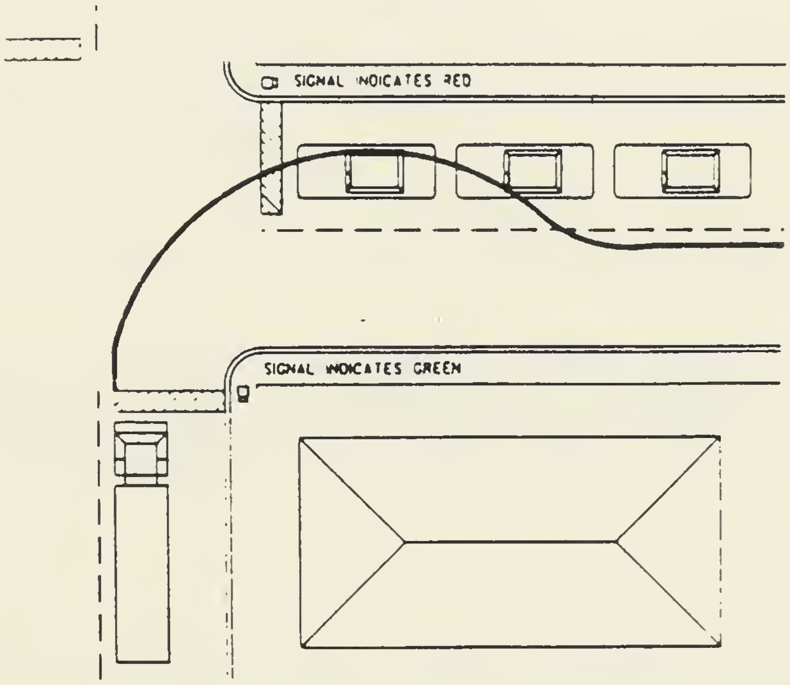


Figure 21. Truck turning path in restrictive intersection (DeCabooter et al.)

As the truck begins the right-hand turn, the required swept path includes a portion of the opposing traffic lane. If opposing traffic were queued up at a red signal, the truck would be gridlocked. If traffic queued up at the red signal tried to maneuver away from the truck, safety hazards could arise. Or, if the truck is turned in such a way as to avoid encroachment on opposing traffic lanes, the trailing edge may encroach onto curbs, strike roadside appurtenances, and in the worst case scenario, come into contact with pedestrians.

Although reconstructing all restrictive curves to accommodate a C-70 design vehicle may be the most effective way to mitigate future offtracking problems, due to construction and right-of-way costs it is also the most unrealistic. DeCabooter, et al. (1989) have compiled a list of measures that might be tried before resorting to full-scale reconstruction, these include:

- Prohibit long truck operation during rush hours.
- Restrict operation to vehicles with special equipment (such as steerable rear axles).
- Restrict right turns.
- Remove parking.
- Offsetting the location of centerline.
- Prohibit rush hour parking.
- Less restrictive traffic control measures.
- Increase sight distance.
- Minimal widening if possible.
- Diversion.
- Meter cross-traffic flow through installation of upstream signals.
- Increase driver skills.

A number of these measures are currently being tested in Montana with varying degrees of success. However, if allowable truck lengths continue to increase, additional solutions will need to be developed, implemented, and enforced.

SUMMARY:

The four principal conditions that lead to maximum offtracking are long trailer lengths, slow speeds, small turning radii, and large curve arcs. Due to Montana's liberal truck configuration standards, the large number of diamond-type interchanges, and the fact that truck routes on Primary and Secondary System roads commonly traverse urban areas and smaller cities, these conditions frequently occur in combination with each other. The results of these cumulative conditions are worst-case offtracking impacts such as disruption of traffic flow, damage to roadside appurtenances, and endangerment of pedestrians.

In an effort to accommodate the needs of the trucking industry, Montana currently allows truck configurations that exceed interchange and urban intersection design standards. To the casual observer, it may appear that this liberal policy has not resulted in extensive damage or traffic problems related to offtracking. However, based on field observations,

this is not because offtracking problems are uncommon. The fact that these problems do not stand out can be attributed to effective maintenance programs and the courtesy of other drivers.

If Montana adopts the WASHTO recommended configurations for trucks allowed on all highways, offtracking problems should decrease. However, if longer truck configurations are allowed in the future, offtracking damage and traffic problems will increase accordingly. Before additional allowances are made to Montana's existing truck regulations, a thorough study with a scope well beyond offtracking is needed. A comprehensive review of highway safety, gross vehicle weights, axle loads, road damage, maintenance costs, travel times, and design criteria will provide a broader understanding of current and future impacts of heavy trucks on Montana highways. By fully understanding the problems, we can avoid creating unmanageable maintenance problems and driving conditions that may become unpalatable to non-commercial drivers.

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